

"Made available under NASA sponsorship
in the interest of early and wide dis-
semination of Earth Resources Survey
Program information and without liability
for any use made thereof."

~~KB/Don't~~
E7.3-11161
CR-135755

UTILIZATION OF REMOTELY-SENSED DATA IN THE
MANAGEMENT OF INLAND WETLANDS

Virginia Carter
U.S. Geological Survey
Washington, D.C. 20244

Doyle G. Smith
U.S. Geological Survey
Washington, D.C. 20244

BIOGRAPHICAL SKETCH

Virginia Carter is an Aquatic Biologist for the U.S. Geological Survey, specializing in wetland ecology, remote sensing of wetlands, and spectral reflectance studies of marsh vegetation. Mrs. Carter received her B.A. from Swarthmore College and her M.S. from American University. She is a member of the Atlantic Estuarine Research Society and the American Society of Photogrammetry. She is a co-investigator on both an ERTS-1 and SKYLAB investigation of Wetland Ecology at the American University in Washington, D.C.

Mr. Smith is a Research Specialist with the Topographic Division of the USGS. He has a B.S. (C.E.) from the University of Colorado and is a member of Sigma Tau and Tau Beta Pi Honorary Societies. He recently completed additional work in ADP (Automatic Data Processing) equipment and programming and 9 months of advanced training in applied optics at the University of Rochester Institute of Optics. Mr. Smith has been assigned to the research staff of the Topographic Division since July 1966. During the past 7 years, he has been active in the design, calibration, and testing of optical and electronic surveying instruments. Recently, he has been serving in an advisory capacity on practical hardware requirements for calibration of RBV (Return Beam Vidicon) camera components and for proposed special processing systems for thematic mapping with SKYLAB and other space imagery.

Analysis of ERTS data referenced in this paper supported by NASA Contracts NAS 5-21752 (The American University-UN006), S-70243 AG (The U.S. Geological Survey-IN-385), and NAS 272 (The U.S. Geological Survey-I-414).

Original photography may be purchased from
EROS Data Center
10th and Dakota Avenue
Sioux Falls, SD 57198

N73-33314
UNCLAS 01161
G3/13
CSCL 08H
(E73-11161) UTILIZATION OF
REMOTELY-SENSED DATA IN THE MANAGEMENT OF
INLAND WETLANDS (Geological Survey) 15 p

ABSTRACT

Remote sensing provides a powerful tool to meet critical management needs for inventory and classification of inland wetlands as well as for evaluation of the wetland role in the hydrologic cycle, identification of significant wetlands for wildlife preservation, and monitoring of wetland change. Remotely-sensed data are being presently utilized for wetland management in the Dismal Swamp (Virginia-North Carolina) and in wetlands of central and southern Florida.

Congress recently authorized the Department of the Interior to conduct a comprehensive study to establish the feasibility of preserving and protecting the Great Dismal Swamp. The Dismal Swamp is partly owned by the Department of the Interior and is of importance to the U.S. Army Corps of Engineers, the U.S. Department of Agriculture, and numerous state and local organizations as well. High altitude photography flown by U-2 aircraft can be used for gross vegetation mapping, boundary determination, and selection of sites for intensive study. Low altitude photography is useful for more detailed mapping. Black and white orthophoto quadrangles currently under preliminary stages of preparation in the U.S. Geological Survey will provide up-to-date maps of the Swamp at 1:24,000 scale. ERTS (Earth Resources Technology Satellite) provides the big picture--the entire Swamp is visible on one ERTS frame--and permits observation of seasonal change and monitoring of significant ecological shifts.

In southern Florida, ERTS is providing information for water management in the wetlands north and south of Lake Okeechobee where droughts place significant demands on water that is also needed for maintenance of the Everglades National Park. Water level and precipitation data are collected in near real time by the DCS (Data Collection System). These data are correlated with ERTS imagery that portrays the areal extent of standing water for prediction and management of water flow.

INTRODUCTION

Management problems with inland wetlands in the United States are coming into sharp focus in a new era of public concern for the environment. State and local governments--e.g., Connecticut, Rhode Island, Massachusetts, Delaware--are mandated by legislation to inventory and regulate uses in inland wetlands. On the Federal level, wetland classification on an overall national basis is a controversial and challenging problem. Preservation and protection of unique wetlands is often a Federal task. Wider recognition and better understanding of wetland values have been followed by concern that competing usages as exemplified by agriculture, residential housing, and industrial growth may destroy vast acreages of valuable natural habitat, potential water supply, or recreational and scenic potential. The extent to which wetlands can be considered a multiple-use resource remains to be established.

Most of the needs and requirements for wetland management on the local, state, and national level can be placed in two general categories:

1. Basic research to establish criteria for decision making.

This need is pointed up by the scarcity of current data relating to the hydrologic relationships of inland wetlands--recharge, discharge, flood storage, and water quality. Only a few local or regional studies have been made such as those on the prairie potholes by Eisenlohr et al., 1969. Another area where additional research is needed is exemplified by a recent paper by Gupta (1972) which is entitled "The Economic Criteria for Decisions on Preservation and Use of Inland Wetlands in Massachusetts."

2. Near real-time information systems to provide wetland managers with information for inventory, classification, and monitoring of wetlands and for water-resource management decisions.

Remotely-sensed data can provide a powerful tool to meet needs in both categories. For example, Gupta's evaluation criteria for wetlands include land-use contrast (what is the surrounding area like?--urban, rural, etc.) and land-form contrast (what is the topographic relief in the area?). Both of these parameters can be easily measured by aerial photography or even ERTS imagery.

The advantages of applying remote-sensing techniques to solve problems in category two are several:

- A. Reduction in costs and manpower for extensive ground surveys.

- B. More rapid completion of inventory or mapping.

- C. More efficient monitoring and change detection, whether seasonal, successional, or manmade.

- D. Collection of multipurpose data useful to future projects and projects not under consideration when data collection was planned.

The disadvantages of using remote sensing include:

- A. The necessity for field checks or "ground truth" data.

- B. The difficulties encountered in scheduling simultaneous ground data collection for subsequent interpretation of the remote-sensing imagery data.

C. The lack of efficient storage and retrieval methods for the large quantities of data generated by remote sensors such as the ERTS-MSS (Earth Resources Technology Satellite-Multispectral Scanner) or low altitude cameras.

To illustrate the utility of remotely-sensed data to the field of inland wetland management, this paper will discuss applications in the Great Dismal Swamp of Virginia-North Carolina and in the Water Conservation District of southern Florida, which includes Lake Okeechobee, several water conservation areas, and the Everglades National Park.

THE GREAT DISMAL SWAMP

In 1972, Congress authorized the Department of Interior to conduct a comprehensive study of the Great Dismal Swamp and the Dismal Swamp Canal. The study is designed to determine the desirability and feasibility of protecting and preserving the ecological, scenic, recreational, historical, and other resource values of the Swamp and Canal and to consider the alternatives for preservation in terms of effectiveness and cost. Consideration must also be given to potential alternative uses of the water and related land resources for residential, commercial, industrial, agricultural, and transportation services. Eight Federal agencies are participating in the investigation, including the U.S. Geological Survey, which is responsible for water dynamics and mineral data. The study is presently being coordinated through the Boston Office of the U.S. Fish and Wildlife Service under the direction of Robert H. Shields.

The Great Dismal Swamp is a vast wooded swamp or forested bog straddling the Virginia-North Carolina border. The Federal Government owns the Dismal Swamp Canal and the Dismal Swamp National Wildlife Refuge, an area of about 49,000 acres recently donated to the Department of the Interior by the Union Camp Corporation through the Nature Conservancy. The Swamp has been considerably modified by man in his many attempts at drainage. Surface water in Lake Drummond (about 6 feet deep and 2-1/2 miles in diameter) is used for operating the locks on the Canal. The lake, drainage ditches, canals, and roads may be clearly seen in color IR photography taken by NASA U-2 in December of 1972. Approximately eight photographs at a scale of 1:120,000 are needed to show the entire Swamp and major drainage.

While estimates of the original size of the Swamp have been as high as more than one million acres, the study area recently designated by the U.S. Fish and Wildlife Service (Press Release/USDI, July 28, 1973) comprises approximately 210,000 acres considered to be viable wetland. Choice of the study area (Figure 1) by the U.S. Fish and Wildlife Service was assisted by the use of NASA color IR photographs and low altitude black and white photographs taken in conjunction with a U.S. Geological Survey mapping project. Black and white orthophoto quadrangles currently under preliminary stages of preparation by the U.S. Geological Survey will provide up-to-date maps of the entire Swamp at a scale of 1:24,000. Fifteen of these maps are required for full coverage.

GREAT DISMAL SWAMP STUDY AREA

VIRGINIA NORTH CAROLINA

PL 92-478

UNITED STATES
DEPARTMENT OF THE INTERIOR

FISH AND WILDLIFE SERVICE
BUREAU OF SPORT FISHERIES AND WILDLIFE



COMPILED IN THE DIVISION OF ENGINEERING
FROM SURVEYS BY U.S.G.S.

BOSTON, MASSACHUSETTS

JUNE 1973

Scale 0 8000 16000 24000 32000 FEET
Scale is Approximate

LEGEND

Primary Study Area
Water Study Area

Figure 1. Great Dismal Swamp Study Area



Figure 2. Enlarged ERTS-MSS 7 (2/13/73) winter image showing the Great Dismal Swamp and associated drainage systems.

ERTS imagery provides the big picture--the entire Swamp and its geographical setting are visible on one ERTS frame. Figure 2 is an enlargement of a part of an ERTS-MSS image (#1205-15150-7) taken in February 1973. Comparison of this image with Figure 1, the map of the Study Area, gives a good indication of the utility of ERTS data in determination of wetland boundaries. Many of the roads and canals may be clearly identified on a 1:250,000 enlargement of the ERTS image, and a reliable map could be constructed of similar areas in the future without the need for extensive and repetitive field work or low altitude aircraft coverage.

Hydrologic studies inside and outside of the formal study area will consider water conditions and movement within the Swamp as well as drainage into and surface and sub-surface flows out of the Swamp. Remote sensing data can contribute to these studies in several ways:

1. Both ERTS images and aircraft photography show surface drainage patterns--surface input and output can be identified and studied. Figure 2 shows the major Swamp drainage clearly, with streams entering from the Suffolk Scarp to the west of the Swamp and exiting to the south, east, and north. Once surface drainage is located, detailed studies of discharge and water quality can be done as needed.

2. Water relations and drainage patterns within the Swamp can be observed with photography or imagery taken during the winter, when deciduous trees are leafless. Thematic extractions from ERTS data show standing water beneath trees and other moisture conditions. This is discussed further under subheading "Autographic Theme Extraction System" below.

3. Aerial photography can be used to establish areas for detailed study, such as the drilling of observation wells, location of stream gauges, and observation of stress.

4. High and low altitude aerial photography and ERTS imagery can be useful for vegetation mapping, whether gross or detailed. The various vegetation communities are associated with differences in water level and soils, discussed later under the subheading "Vegetation Mapping."

5. Thermal imagery of the Dismal Swamp taken from low altitude during the winter could yield important information on areas of ground-water inflow. As wetlands represent a surface-groundwater interface, the movement of water beneath the surface is as important to the Swamp's existence as the surface water.

Autographic Theme Extraction System

The U.S. Geological Survey is developing an Autographic Theme Extraction System (ATES) to apply photographic and digital processing to images to obtain specific theme isolations, which retain the geometry and resolution of

the original image. These extractions, or spectral images, are based on distinctive densities, or combinations of densities, and are presently being done on an experimental basis with ERTS-1 and SKYLAB images (Smith, 1973).

ERTS-1 images from October 11, 1972 (1079-15142-5,7), and February 13, 1973 (1205-15150-5,7), have been used as the base for a series of wetlands extractions in the Dismal Swamp. The isolated theme data are stored as two-level or binary theme extractions in the form of a photographic transparency. Two or more of the properly processed spectral images can be combined into a photographic composite to cancel out unwanted or spurious data and isolate the desired theme.

Figure 3 is an enlarged MSS-7 positive (10/10/72) of the Dismal Swamp on the North Carolina-Virginia border south of Norfolk, Virginia. Part of Currituck Sound and Great Swamp in North Carolina can be seen on the east. A bend in the Chowan River including a part of the Chowan Swamp appears in the southwest corner. Figure 4 is a density clipping of the February 13, 1973, original to isolate wooded swamp (grey). Figure 5 reduces the picture to the binary form where the wooded swamp is white except where there is standing water, dense white cedar, or snow in clear-cut areas (black). Salt marsh and snow-covered agricultural fields are also black. Figure 6 is a change-detection extraction. The white areas show where MSS-7 differs from October 10, 1972, to February 13, 1973. Clouds are evident, as are seasonal differences in areas of deciduous trees in which water is standing. Figure 7 shows the wettest area of the swamp, dense white cedar, and also the urban communities of Norfolk and Suffolk (black). Figure 8 shows the drier deciduous, or low flat evergreen areas where snow can accumulate (white).

Vegetation Mapping

Use of color IR photography for vegetation mapping in wetlands has increased recently (Anderson and Wobber, 1972; Seher and Tueller, 1973). Plant associations with distinct or unique tonal signatures may be differentiated and mapped to a scale commensurate with the scale of the photography. Where sufficiently large plant associations exist, as in the Dismal Swamp, it seems highly possible that mapping of vegetation types can be done from ERTS, using the ATES approach.

The flora of the Great Dismal Swamp is a diverse mixture of northern and southern species. Many plants primarily associated with the swamplands of the deep South reach their northernmost extent here and in the Pocomoke River Swamp on the western shore of Maryland. The Pocomoke River Swamp differs, however, from the Dismal Swamp in being under tidal influence, with an average rise and fall of water of 2.8 to 3 feet (Beaver and Oostang, 1939).



10 miles

Scale is approximate

Figure 3. ERTS-MSS 7 (10/10/73) fall image showing the Great Dismal Swamp. Currituck Sound is on the right and the Chowan River appears in the southwest corner.



10 miles

Scale is approximate

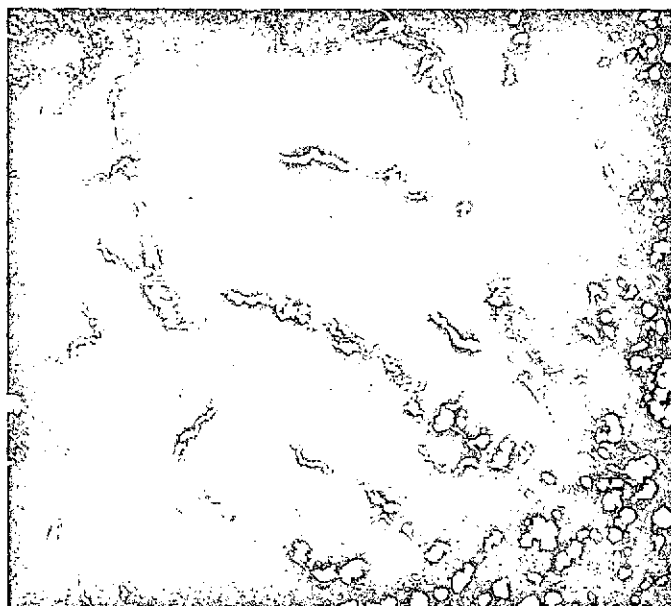
Figure 4. Density enhancement of ERTS 2/13/73 image. Wooded swamp is grey.



10 miles

Scale is approximate

Figure 5. Binary extraction from the ERTS 2/13/73 image. Wooded swamp is white except where there is standing water, dense white cedar, or snow in clear-cut areas (black). Salt marsh and snow-covered agricultural fields are also black.



10 miles

Scale is approximate

Figure 6. Change detection extraction showing where MSS-7 differs from October 1972 (black) to February 1973 (white).



10 miles
 Scale is approximate

Figure 7. Theme extraction showing wettest areas of swamp, dense white cedar, and urban communities of Norfolk and Suffolk.



10 miles
 Scale is approximate

Figure 8. Theme extraction showing drier deciduous or low, flat evergreen areas where snow accumulates.

Distribution of vegetation in the Swamp is controlled by moisture, soil, and light conditions. Vast acreages have been logged once and are now covered with second growth plant associations. Levy (1973) and Meanley (1972) have indicated that several discrete phytocommunities can be distinguished. Some of these are identified on Figure 9 (a black and white copy of color IR photograph taken by NASA-U2 at an altitude of 60,000 feet). The hydric or deep water swamp (A) is characterized by cypress, gum, and maple (deciduous) growing in as much as 2 feet of water. Dense, monospecific stands of Atlantic White Cedar (B) (evergreen) occupy areas with very little standing water. The evergreen shrub-bog community (C) is also in areas with little surface water and is characterized by broad-leaved evergreen shrubs, bay trees, and pond pine. These communities are low and relatively open, as are the revegetating clear-cut areas and are often referred to as "lights." A pond pine-Ilex association (D) may be differentiated from (C) by its light tone. The semi-hydric, or mixed swamp hardwood forest (E), grows in areas without standing water most of the year. Gum, red maple, water oak, and bay dominate this forest type, and the evergreen understory distinguishes it from the denser hydric forest in winter photography. The mesic or hammock forest (F) is rather dry and contains deciduous oaks, beeches, tulip poplar, and holly. Pure stands of pine also grow in some areas. Distinguishing between semi-hydric and mesic forest is difficult, but winter photography and imagery may provide a useful method for the discrimination.

SOUTH FLORIDA

Water supply for the east coast of Florida, with a population of 2-1/4 million, depends on retention of water in four major impoundment areas or shallow wetlands (less than 3 feet deep) south of Lake Okeechobee. These large water conservation areas (1,400 square miles) serve also as water supply for the Everglades National Park. Ultimately, the water discharge to the Gulf of Mexico is by slow-moving sheet flow through the Shark River Slough. The Big Cypress Swamp near the west coast of southern Florida also supplies a part of the water necessary to maintenance of the dynamic environment of the Everglades.

Data Collection Platforms (DCP's) in the impoundments, the Everglades, and the Big Cypress Swamp presently supply near real-time data on water level and precipitation by satellite relay to the Miami Office of the USGS via NASCOM (Wimberly, Higer, Cordes, Coker, 1973). The data are analyzed and disseminated to water management agencies such as the U.S. Corps of Engineers and the Central and Southern Florida Flood Control District.

ERTS-DCP information can be used immediately for water management and correlated with enhanced ERTS imagery, which delineates the areal extent of fresh water inundation.



5 miles

Scale is approximate

Figure 9. Black and white reproduction of NASA-U2 color IR photograph of the Dismal Swamp. (A) hydric (deep water) swamp, (B) Atlantic white cedar, (C) evergreen shrub-bog association, (D) pine-Ilex association, (E) semi-hydric swamp, (F) mesic forest.

Water storage information developed using this system can benefit both the water users of southern Florida and the Everglades by providing a more reliable and timely source of information for decision making. Maintenance of data collection stations is less of a problem with DCP's than analog types of ground stations because malfunctions are detected immediately. Expansion of the Data Collection System to include sufficient water budget parameters to calculate evapotranspiration is presently under consideration in south Florida.

SUMMARY AND CONCLUSION

ERTS data and aerial photography are proving to be a useful tool for the inventory and management of inland wetlands. Two examples of the application of remotely-sensed data to specific wetland management needs or requirements are discussed in this paper.

Studies of the Great Dismal Swamp are utilizing ERTS imagery and color IR photography in (1) study area selection, (2) field inspection, (3) vegetation mapping, (4) identification of drainage characteristics and moisture regime, (5) location of intensive study areas and (6) detection of change. Thematic extractions of ERTS data made using the United States Geological Survey's Autographic Theme Extraction System are aiding analyses of swamp hydrologic regime and providing information pertinent to quick recognition and inventory of wetlands from ERTS.

DCP's in south Florida wetlands provide near-real time data for water resource managers. Data relayed by satellite can be entered into models to provide predictive data and water storage information for long-term and short-term decision making.

REFERENCES

- Anderson, R. R., and Wobber, F. J., 1973, Wetlands Mapping in New Jersey, Photogrammetric Engineering, 39: 353-358.
- Beaven, George F., and Oostang, Henry J., 1939, Pocomoke Swamp: A Study of a Cypress Swamp on the Eastern Shore of Maryland, Bulletin of the Lorrey Botanical Club, 66: 367-389.
- Eisenlohr, W. S., Jr., et al., 1972, Hydrologic Investigations of Prairie Potholes in North Dakota, 1959-68, Geological Survey Professional Paper 585-A, 101 pp.
- Gupta, T. R., 1972, Economic Criteria for Decisions on Preservation and Use of Inland Wetlands in Massachusetts, Journal Northeastern Agricultural Economics Council 1(1): 201-210.
- Levy, G., 1973, Personal Communication, Old Dominion University, Norfolk, Virginia.

Meanley, Brooke, 1972, Swamps, River Bottoms and Canebrakes, pp. 27-40, Barre Publishers.

Press Release, U.S. Department of the Interior Fish and Wildlife Service Regional Information, Great Dismal Swamp Study Area Identified, July 28, 1973.

Seher, J. Scott, and Tueller, Paul T., 1973, Color Aerial Photos for Marshland, Photogrammetric Engineering, 39: 489-499.

Smith, Doyle G., 1973, Autographic Theme Extraction System, to be presented at the 7th UN Regional Cartographic Conference for Asia and the Far East, Tokyo, Japan, October 15-27, 1973.

Wimberly, E. T., Higer, A. L., Cordes, E. H., and Coker, A. E., 1973, Acquisition and Processing Program of ERTS Data in South Florida, ERTS Type II Progress Report.